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Sewage treatment and disposal options for rural or unsewered domestic properties

ABSTRACT

On-site wastewater treatment can be handled in four ways. Basic septic tanks are the traditional method with large dispersal fields and filtered/pumped tanks also requiring secondary treatment by a large ground area. However, there are now more sophisticated methods available such as activated sludge systems which involve two stages of treatment in the tanks and rely less on the dispersal field to treat as the effluent discharged is higher quality. Advanced sewage treatment systems provide treatment within the tank followed by treatment by recirculating reactors of sand, or in recent developments, a special fabric. The latter requires minimal land to be set apart for ground treatment as the effluent is of sufficient quality that allows it to be reused. High standards of treatment cost more but those system require less land to be set apart for treatment.

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INTRODUCTION

Like many other 'devices', septic tanks and on-site wastewater treatment systems have steadily evolved and been improved in recent decades. However, many of us have memories of a simple tank connected to a soakage field on an overly large allotment because domestic effluent from septic tanks must be distributed into the soil at a rate which allows the soil to absorb and treat it. Local body laws do not permit effluent to be discharged into a creek, over a gully, into a neighbouring property, into a pond or cause a health nuisance.

Just as the conditions for rural houses can vary immensely (size of house, section/farm soil type, climate and environmental sensitivity), so too the design of the on-site sewage systems must equally vary where necessary to accommodate these conditions.

On-site sewage systems should be individually site specific. The lack of a connection to a centralised treatment plant can limit further subdivision either of individual lots or, because of groundwater pollution. The American Environmental Protection Agency (EPA), a federal agency, with responsibilities for protecting the environment, has placed constraining orders on any future expansion of many USA towns ("cities") because many older septic tanks in them are failing, polluting streams and ground water. Some 40 million households in the USA (over 25% of all homes) rely on septic tanks.

Numerous systems are available in New Zealand to treat wastewater. Not all systems provide full treatment, however. Some at best offer only a temporary solution, until the area of development is connected to a reticulation system, or they rely heavily on the soils to provide much of the treatment. Price is frequently a good indicator of performance. Cheap installations invariably require regular maintenance and replacement of components, and/or create unacceptable environmental pollution. Compact systems are now available on the market that readily and reliably treat any domestic wastewater to clarity standards good for all but potable use. This paper reviews the options available in New Zealand for on-site sewage treatment.

STANDARDS

There are four systems or processes generally considered for on-site wastewater treatment. The key performance factors for evaluating sewage treatment systems are the reduction of Total Suspended Solids (TSS) and reduction of Biological Oxygen Demand(BOD_5) at 5 days. Generally, household waste enters the septic tank with a BOD_5 of around 370 mg/litre. Reduction in nitrogen levels may also be a desired outcome of treatment. The TSS are around 340 parts per million (ppm). The Standard, AS/NZS 1546.1:1998 *On-site Domestic Wastewater treatment Units: Part 1 Septic Tanks* states that secondary sewage treatment should produce the standards of 20 mg/l & 20 ppm (20/20). American standards for new installations require 10/10, hence modern American-designed systems must produce a higher quality effluent than those locally designed for New Zealand or Australia. In a recent survey, the Hawkes Bay Regional Council found that less than 25% of the systems tested within its region met the Council guideline of 30/30 (BOD/TSS), AS:NZS 1547:2000 p15 requires 20/30). Regrettably this points to almost systemic failure when the technology exists for vastly better results to be achieved. As is the case with the leaky building syndrome which affected many houses, the failures can be attributed to four issues: poor design, poor quality equipment (materials), poor installation and poor maintenance. This is an unfortunate situation particularly when expert systems are available that are capable of transforming the way we handle sewage – from a costly, offensive waste product to a recycled resource.

A typical New Zealand household uses around 1,000 litres of water each day. "Solid matter" when dried only amounts to 20 – 40 litres per year, so a properly used tank requires cleaning only every 5 to 8 years or longer (Bounds:1994). Even the solid will break down over a period of years in the tank. Pumping the tank clean too frequently disrupts this anaerobic breakdown process.

ESSENTIAL COMPONENTS

Watertight tanks

For a successful modern household system, the fundamental component is a properly sized (large) watertight tank. Water-tightness has been an issue with installed tanks. Being watertight in the manufacturer's yard is no help if the tank fails (leaks) in service. Water seeping into the tank greatly reduces its effectiveness to treat sewage. Sewage seeping out pollutes the environment near the tank (probably near the house). It would then be pointless to fence off a dispersal field when untreated effluent is escaping at the tank. Some manufacturers wisely install the tanks themselves or allow only specifically trained personnel to install them.

1 The Traditional Septic Tank

The simplest systems are cheap to install, provide only minimal treatment in the tank and rely heavily on the home owner to manage what 'goes down the drain' and on the soil of the soakage area to protect the environment (Crites & Tchobanoglous, 1998). There are just two components of the system: the tank and the treatment area soil. In effect, the ground provides the secondary treatment so the area should be fenced off from stock and human access and designated for effluent treatment. The soil conditions of particular sites, their topography and their climate differ greatly and so does the treatment each site can offer. Any malfunction or misuse of the system readily leads to an unsanitary environment (Browne,1974).

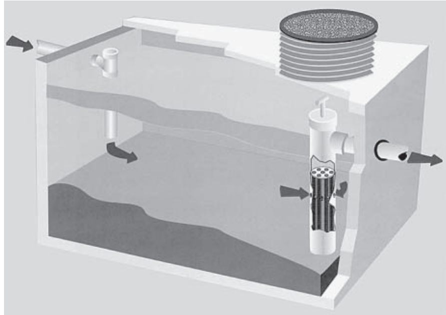

Figure 1. A conventional gravity flow septic tank fitted with an outlet filter.

It is not uncommon in rural or small resort areas for property owners to rely on poorly performing septic tanks and at the same time pump bore-water from very close to a dispersal field/treatment area. Although it is illegal to locate a dispersal field within 100 metres of an existing bore, there is no similar constraint on where a bore might be sunk if a septic tank field already exists.

2 Low Pressure Dosing Systems

A tank with an outlet filter and a pump is a more advanced and effective system. The filter ensures that the drainage field does not get clogged with debris flushed out of the tank when there is a sudden heavy in-flow. The pump can be controlled to dose the field at regular intervals over 24 hours. This is much better than just relying on the morning surges that occur in most households. A filter can be retrofitted to existing tanks for a few hundred dollars and can enhance performance provided the tank and dispersal field is otherwise in good condition. The tank has to be large enough (ideally 4,000 to 6,000 litres) to store solids, the inflow between pumping intervals and many hours of effluent storage should there be some major breakdown (Bounds, 1997). A pumped tank does not rely on gravity to drain the tank so the dispersal field can be on ground higher than and some distance from the tank.

A further advantage of a pump is that the drainage field is more likely to be evenly dosed. This enables more micro-organisms in the soil to consume the effluent, leading to more effective treatment. Today's Low

Pressure Effluent Dosing (LPED) systems, using computer design and flow control assemblies to precisely dose each trench, are in balance with the soil and so provide an adequate level of treatment over many years.

3 Secondary Treatment Systems

In the more advance category of treatment systems, packaged treatment plants or Advanced Wastewater Treatment Systems (AWTSs), the system provides much higher levels of treatment in the controlled environment of the tank. Effluent that is pumped from the tank is sufficiently free of suspended solids that it can be distributed through irrigation lines in places such as bark gardens. The quality of effluent discharged is similar to that accepted from municipal treatment stations. The dispersal area can often be located within the house garden area and does not need to be separately fenced off from stock. Most AWTSs are generally fairly basic treatment plants producing BOD/TSS of 20/30 under ideal conditions. They thus can just meet the AS:NZS1547:2000 standards. However, because their performance is often of a lesser standard, it is wise to avoid irrigation disposal areas under lawns or areas involving recreational use (Miller 2003).

4 Advanced Sewage Treatment Systems

At the top end of on-site systems are those that are referred to as Advanced Sewage Treatment Systems (ASTS) generally producing high quality effluent: BOD/TSS of 5/5. These systems have three major components:

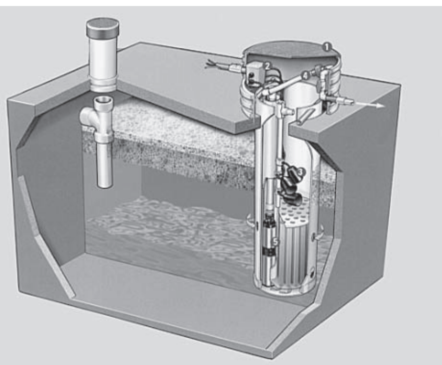

Figure 2. An advanced septic tank fitted with a pump protected by an outlet filter.

- a large tank fitted with an exit-filter,
- a *reactor* that purifies the effluent after it has left the tank (secondary treatment); and
- the ground treatment to polish up the effluent before it evaporates, is used by plants or trickles through to the ground water (Miller, 2003).

If water is to be re-used by humans the system should include a UV device or chlorine dosing to kill remaining pathogens.

The reactor can serve a single dwelling or serve a multi-lot subdivision. Some of these systems use bottomless reactor beds that allow effluent to trickle through the sand or peat then continue to be treated by the soil (sand/shingle/gravel) beneath, but above the water table, giving the filtered effluent final polishing as it enters the environment. The reactor medium can be graded sand, a special textile or sometimes peat. They are usually referred to as PBRs (Packed Bed Reactors), especially those with specially selected and graded sand and gravel (Standards New Zealand, 2001). The reactor medium should not be expected to act as a filter as it is the habitat for micro-organisms that digest the remaining fine solids in the effluent (Baldwin, 2003). The filtering process should therefore always occur before the reactor.

More sophisticated sand reactors include re-circulating packed bed reactors rPBRs where the effluent, having trickled down through about 600 mm of specially graded sand, is gathered and re-sprayed over the reactor material. The Orenco Advantex unit, uses a specially designed textile fabric not sand. After each pass through the reactor, only about 30% of the effluent is diverted to the final dispersal field, so most effluent passes through the reactor several times (Orenco, 2003).

Sand reactors that receive well-filtered effluent have a long history of reliable service but the quality and grading of the sand is critical. In setting aside land for the sand reactor, a rule of thumb is that each household needs about 10m^2 of sand filter surface. A single house sand filter units need to be larger (16 m^2). The size of the filter must be designed to suit the occupancy (number of bedrooms) in the house. As there are storage tanks in the system, they can store semi-treated effluent for around 24 to 48 hours of normal inflow levels. Sewage solids always remain in the collector tanks at each household.

Although the theory of spraying effluent on to sand or textile is simple, the dosing rate needs to be precisely correct to maintain optimal treatment. The system will become clogged and fail if the reactor is relied on to act as a filter. Several systems available in New Zealand fail because the tanks do not produce well filtered effluent. In the worst cases of clogging, the sand has to be removed and replaced. This type of problem used to occur with some of the old Ministry of Works systems, giving sand reactors a poor reputation. A further problem with sand filters/reactors is the inconsistent quality of the sand and the skill (or the lack) of the constructors. Poorly placed or graded sand can diminish the reactor's performance so designers have sought more consistent filters (Andrews:2003).

Orenco, an America manufacturer, has addressed this problem by developing a special fabric to host the micro-organisms. They have also developed the methodology for precise dosing. A very real advantage of the Advantex units is that if the reactor fabric does get clogged, the fabric can be readily lifted, and simply hosed down – a task

Figure 3. Advanced Treatment System with the recirculating fabric packed bed reactor attached on top. The system is factory assembled.

Figure 4. Dave Miller inspects a fabric recirculating packed bed reactor located close to the residence. Treated water of BOD5/TSS of less than 5/5 ppm safely irrigates the garden.

taking just minutes. Extreme clogging, if this ever occurs, can be remedied by replacing the fabric units, in minutes. Cases of extreme neglect do not occur often, nor do they cause instant failure of the system.

The Advantex reactor unit has an area of about 2.0 m^2 so is a much more compact unit than a sand reactor, and properly sized for the loading, it can out-perform sand reactors. The Advantex units are the only reactor units to gain National Science Foundation (NSF) approval. It is usual for a single household fabric reactor unit to be placed on top of the tank. (Simmie, 2004).

RECYCLING WATER

The Advanced Treatment Systems (and well functioning sand rPBRs) not only treat the effluent to protect the environment and public health, but also produce recyclable water. For added health precautions, depending on its end use, the water can be treated with chlorine or UV light. Unless the effluent is very clear (very low TSS), UV treatment might be unsuccessful. Thus systems such as the textile re-circulating reactors that produce very low BOD and TSS enhance the effectiveness of the later disinfection processes.

The treated effluent can be used for garden or lawn irrigation, non-potable uses such as toilet flushing, vehicle car-washing, fire-fighting or merely safely recharging groundwater, lakes or the sea. Chlorination can add undesirable chemicals to the environment, making the effluent less acceptable. The treatment process does not deal with organisms such as cryptosporidium so the treated water is not fit for consumption even though it can be very clear in appearance.

COSTS OF SYSTEMS

The golden rule of sewage treatment, like so many other facets, is that you only get what you pay for. Sewage will only be treated if all the relevant items are correctly evaluated, designed for and constructed. As a basic ball-park figure the costs to install the following system types in New Zealand are:

1 Traditional Septic tank with gravity soakage (say 100 metre trench) $4-5,000

2 Low Pressure Effluent Dosing System with Biotube filter and OSI flow control assemblies, low head pump and 200 metres of trenches $7-8,000

3 Standard (basic) AWTS Treatment System using low head pumps $9-11,000

4 Advanced Sewage Treatment System (i.e. American Re-circulating Textile Packed Bed Reactor-rtPBR) $12-13,000

Against these relative costs, one has to balance items such as the cost/value of land.

Feature	1. Standard Tank	2. Pumped Tank with biotube filter	3. Standard treatment system	4. Advanced Treatment system
Filter	No	Yes	Yes	Yes
Compartments	No	No	Yes	Yes
Pump	No	Yes	Yes	
Pump life	No pump	3-4 years	3-4 years	25-30 years
System life	15-20 years	15 –20 years	15-20 years	100-125 years
Land set aside (fenced)	Up to 400m^2	Up to 400m^2	Bark gardens can be used	Not essential. Water can be recycled
Tank pump outs	4-6 years	4-6 years	4-6 years	8-12 years
BOD_5 370 ppm inflow	160 ppm (57% reduction)	130 ppm (65% reduction)	20 ppm (95% reduction)	5 ppm (99% reduction)
TSS 340 ppm inflow	80 pmm (76% reduction)	30 ppm (91% reduction)	30 ppm (91% reduction)	5 ppm (99% reduction)

Table 1: Systems compared. Note the vastly superior treatment and system life expectation of the recirculating fabric packed bed reactor.

Although they might cost $6,000 to $8,000 more than the basic septic tank system, the rtPBs do not require land to be set apart and fenced off for effluent treatment. Thus a site area saving of 200 to 400m^2 per lot is possible. Other benefits include the reduced health hazard, conservation and re-use of increasingly scarce water supplies.

MAINTENANCE

Every wastewater treatment system requires regular inspection and timely maintenance. Timely inspections and often just minor maintenance work (e.g hosing down a filter) by a trained technician can ensure the environment and public health is protected and problems with the systems are addressed before they become dangerous and/or costly (West, 2001). Firms that are confident in the performance of their products and installations offer comprehensive maintenance contracts that compare very favourably with rates levied by many district or city councils for the maintenance of the intricate aging gravity systems serving municipal areas.

CONCLUSIONS

There are four distinct standards of equipment providing treatment of domestic sewage.

Where land areas, water-table levels and soil types permit, a traditional septic tank may provide adequate service. This is suitable for farmhouses or rural-residential properties. Low Pressure Effluent Dosing Systems are more effective but low-cost, low head stormwater pumps that are often used will require regular maintenance and replacement. Initial savings can be lost in the cost of maintenance and replacing components. The fine weep-holes in drip-lines that allow controlled dosing clog quickly if the quality of the effluent is not maintained resulting in further cost.

The Advanced Sewage Treatment Systems, particularly those with re-circulating textile packed bed reactors are completely designed treatment/water recovery systems. The components are specifically designed to meet the requirements of handling household sewage and effluent. Although their initial cost can be up to twice that of the cheapest basic tank systems, they can provide high-quality re-useable water. Like any sewage treatment system, they require regular (usually annual) minor maintenance but can be expected to perform well for decades and protect the environment. They should be seen as an asset rather than a liability and justify the higher initial outlay.

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